A SURVEY OF TERN ACTIVITY

WITHIN NANTUCKET SOUND, MASSACHUSETTS

DURING THE 2004 FALL STAGING PERIOD

Final Report for Massachusetts Technology Collaborative

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INTRODUCTION

A proposed wind farm on Horseshoe Shoal in Nantucket Sound, Massachusetts, would be the largest offshore wind farm in the United States and one of the largest in the world. Until recently few data have been available to assess the potential risks that offshore wind farm pose to birds. A recently completed draft Environmental Impact Statement (DEIS) has summarized data collected as part of the avian risk assessment for this project (USACE 2004). In response to the proposed wind farm, Mass Audubon has conducted bird surveys in Nantucket Sound over the past two and a half years. These surveys have contributed additional information on avian use of Nantucket Sound and the proposed project area and, in combination with data reported in the DEIS, provide three years of data pertaining to certain aspects of avian risk assessment. The focus of this current report is the third-year of survey of tern activity during the fall staging season, defined as August through mid September.

Several of the largest tern colonies in New England are found within 20 miles of Horseshoe Shoals. Approximately 50% of the North American population of federally endangered Roseate Terns breeds within Buzzards Bay in Massachusetts (USFWS 1998), and in 2004, approximately 10,000 pairs of Common Terns nested on and in the immediate vicinity of South Monomoy Island, Monomoy National Wildlife Refuge (NWR), Chatham (MDFG 2004). Common and Roseate Terns forage within, or pass through, the Sound between early May and late September as they move to and from their nesting colonies, foraging areas, and fall staging sites. Prior to studies initiated by the applicant and Mass Audubon during the environmental review, little was known about the abundance, dispersal, and daily movements of terns during these months in Nantucket Sound. In particular, the use of Nantucket Sound by terns during the migratory staging period was poorly known.

We began surveying the activity of terns in Nantucket Sound in August of 2002. In this report we describe the results of our third year of surveys during the fall migration (i.e. Staging) period. In surveys conducted in 2002 and 2003, the majority of terns recorded were observed near Monomoy NWR or the south shore of Cape Cod (e.g., Perkins, et al. 2002). Fewer terns were seen on Horseshoe Shoal indicating that the Shoal was used less frequently than other portions of the Sound during the survey window. Because of potentially significant variation in environmental variables such as weather, and food availability and distribution, it is crucial to repeat surveys over a minimum of three years to determine whether the patterns observed in any single year are repeated in other years.

We conducted eleven aerial surveys between August 7 and September 24, 2004. The primary objectives of the aerial surveys were to determine the general distribution and abundance of Common and Roseate Terns within Nantucket Sound during the staging period, and to document behavior. Between August 11 and September 23, we conducted six boat surveys in the waters on and in the immediate vicinity of Horseshoe Shoal. The primary objectives of the boat surveys were to document the behavior (e.g., traveling, actively feeding, or sitting on the water's surface), and to estimate the heights at which the terns were flying.

The timing of these surveys was based on the hypothesis that Common and Roseate Terns approach their maximum abundance within the Sound in late summer. During this period the terns move from breeding colonies and summer feeding grounds to their primary premigratory staging areas on or near South Beach in Chatham (Trull, et al., 1999). For example, previous surveys of staging birds in Chatham have produced estimates of up to 7,000 Roseate Terns in early September (Veit and Petersen, 1993). Color-banding studies have demonstrated that the Roseate Terns that stage in Chatham come from colonies throughout the northeastern United States and Canadian Maritime Provinces as well as from Massachusetts colonies. It has been suggested that these late-summer congregations may comprise the entire North American population (Trull, et al., 1999).

METHODS

Data on tern distribution, and abundance on Horseshoe Shoal and in Nantucket Sound was collected primarily using aerial surveys; boat surveys were used to gather information on behavior and flight heights. Our field methods described below were identical to the protocol developed for our second survey of terns during the 2003 pre-migratory staging period (Perkins, et al. 2004b), which were modified slightly from our original surveys in 2002 (Perkins, et al. 2003). These modifications, in brief, included the introduction of a clarified transect width (600 ft) and improved data entry methods. See Perkins, et al. (2004b) for more detailed information. Data analysis methods were slightly (see Analysis of Aerial Survey Data below).

Aerial Surveys

Eleven aerial surveys were conducted between August 7 and September 24 along sixteen fixed, parallel transects oriented north to south (Figure 1). The study area encompassed an irregular polygon extending from 41.65º to 41.37º N and 70.42º to 69.98º W. In total, this polygon comprised approximately 343 square miles or 60 percent of Nantucket Sound; the transects began just seaward of the south shore of Cape Cod and extended southward to an east-west line roughly even with Great Point, Nantucket. Individual transects were positioned at 7,500 foot intervals, and the total combined length of all 16 transects was 247.4 miles. The length of the longest transect was 18.2 miles; the shortest transect was 4.5 miles in length. The actual sample area, calculated as the width of transects (600 ft) multiplied by their combined length (247 miles) was approximately 28 square miles. Thus, the sample area surveyed in 2004 represented approximately five percent of the area of the Sound.

In an attempt to place our survey observations in the broader context of the staging tern population in the immediate vicinity of Nantucket Sound, we surveyed several areas adjacent to the study area between September 7 and September 24 (n=5 surveys). These extended surveys took place immediately after completing each of our last five standard surveys of the season. These extended surveys were timed to coincide with the peak of the staging period. These adjacent areas were surveyed using several non-standardized flight lines along the eastern side of South Monomoy Island (to the southernmost point of the island, approximately 41.54º N), the east and west sides of South Beach (Chatham), and along the east and west sides of North Beach (Chatham and Orleans), with a northern terminus of approximately 41.75º N. These flight lines represent an addition to previous survey methods. These additional surveys typically lasted 15 minutes and covered approximately 26 statute miles. Data from these adjacent-area surveys is not included in survey data from the 11 aerial surveys.

Aerial surveys were flown with a high-winged, twin-engine aircraft (Cessna Sky Master 337) at an altitude of 500 feet, and at an average airspeed of 90 knots. The chosen altitude allowed us to identify birds on the sea surface but also reduced the possibility of flushing the birds from the water surface to another part of the Sound where they might have been recounted. The airspeed was the slowest at which the aircraft could safely fly. Flights were conducted only on days with light to moderate winds (not exceeding 15 knots) and on days with good atmospheric clarity (visibility >10 miles) – by definition we did not attempt to conduct our surveys under randomly chosen weather conditions. Flights usually commenced mid-morning and the average duration of each survey was roughly 3.5 hrs.

Each aerial survey team was composed of a pilot, a recorder in the co-pilot seat, and two experienced observers. The two observers were positioned opposite one another on each side of the plane. All members of the team communicated through an onboard intercom system. The observers verbally communicated all bird sightings to the recorder. The recorder immediately entered this information onto a laptop computer. Geographical location was automatically logged by the computer program, dLog (v.2.0, R.G. Ford Consulting, Portland, OR). We recorded the number and species of all birds and their behavior. Behaviors were categorized using several visual cues. Traveling birds were observed flying at a generally constant speed and height, and in one clear direction. Actively feeding birds were observed flying more erratically than traveling birds, either circling, swooping, or diving. Resting birds were observed sitting on the water's surface. We also recorded starting and ending times, wind direction and velocity, sea state (Beaufort scale), visibility, and percent cloud cover for each transect on every survey. Surveys were conducted over a wide range of tidal stages.

We recorded the number of birds seen on either side of the north-south transects out to a distance of approximately 483 feet on each side of the plane. Approximately 183 horizontal feet on either side of each transect was not visible due to the positioning of windows inside the plane. Thus, we estimated angles of viewing to approximate a "moving window" of visibility 300 feet perpendicular to the direction of travel (Figure 2). Counts of birds were briefly suspended while we were flying the short, east-west legs between transects.

The inclusion of waters outside of the standard grid in 2004 represented a slight modification to previous survey methods. All off-survey tern observations were kept separately from observations from standard grid surveys during a particular flight and off-survey data were not included in the summary analyses. Non-avian species, such as sea turtles and marine mammals, were recorded on all surveys if observed at any point during the survey, including areas outside the study area and along the short east-west legs between transects.

We recorded individual birds to species with the aid of binoculars as needed. Common and Roseate Terns were distinguished, when possible, by their different flight behaviors, shapes, and plumage characteristics. Roseate Terns have shorter, narrow wings (producing quicker, shallower wing beats), proportionately longer tail streamers (in breeding adults), and overall whiter plumage than Common Terns (Gochfeld, et al. 1998). When we could not determine with certainty whether the bird was a Roseate or Common Tern we placed the sighting in a separate category of undifferentiated Roseate/Common Tern species. Any reference to 'terns' is to the combined total number of Roseate, Common, and undifferentiated Roseate/Common Terns. Data not presented in this report are available from the authors by request.

We did not attempt to estimate flight heights of terns during plane surveys *unless* the birds were relatively high (300 ft or higher) such that more accurate height estimates were possible.

Analysis of Aerial Survey Data

We compared relative tern abundance in Nantucket Sound with tern abundance in the three alternative project areas from the USACE DEIS including, the Horseshoe Shoal project area, the Tuckernuck Shoal project area, and the Monomoy-Handkerchief Shoal project area (Figure 1) during this study period. We calculated relative abundance of birds in each project area as a percentage of the total number of birds counted during the entire standard grid survey. We overlaid the boundaries of the three proposed wind farm sites over the standard survey grid and summed all point data within each bounded area that were collected during the aerial surveys. This method differed from methods employed in analysis of 2003 staging period data (Perkins et al. 2004b) in which project areas were aggregated from single-mile units. This modification was employed to give more accurate sampling of terns within project areas. Percent relative abundance of a given species within a geographic unit was calculated as the number of birds observed within each unit divided by the total number of birds for that species observed on each survey. These percentages were compared to the proportional area of each unit to determine if the likelihood of observing terns in a geographic unit was the same as observing terns in the rest of the Sound.

We compared the results from the 2004 staging period with our results from 2002 and 2003. During the 2002 staging period, birds seen resting on sandbars were included in the survey results (Perkins et al. 2003). However, these data were not included in the 2003 or 2004 databases, because it was decided that these data did not reflect tern "use" of the Sound per se. In order to more accurately compare the 2002 data set with those from 2003 and 2004, the resting birds recorded in 2002 were omitted from the analyses.

Additionally, on closer inspection, we determined that several observations of feeding tern flocks just outside the study area boundaries were included in 2002 and 2003 analyses (Perkins et al. 2003 and 2004b). These data were also omitted.

Boat surveys

We conducted boat surveys along a series of transects oriented in two approximately parallel tracks, one mile apart. The positions and dimensions of these transects were selected to sample the waters over Horseshoe Shoal as well as the waters in the immediate vicinity of the Shoal (see Figure 1). For the purposes of this study, we defined the Shoal as the roughly continuous area described by the 20-ft bathymetry line within the Horseshoe Shoal wind project area. The boat surveys began and ended at waypoints in the northeast portion of Horseshoe Shoal, and followed a roughly crescent-shaped route out to and back from waypoints near the southeastern portion of the Shoal, just west of Halfmoon Shoal. Surveys were conducted from a 33 ft powerboat, cruising at an average speed of roughly 17 knots. Surveys lasted approximately 1.5 hours. The total linear length of all transects was 24.9 miles.

The boat survey team consisted of two observers and one recorder, and data collected included numbers of birds seen, species, behavior (feeding, sitting, or traveling), flight altitudes, survey starting and ending times, weather (e.g., rain, clear, percent cloud cover), wind speed and direction (knots), water temperature (°F), sea state (Beaufort), and visibility. Observers were positioned on each side of the boat immediately aft of the wheelhouse, and verbally communicated all bird sightings to the recorder. Data were recorded using dLog as described above for the aerial surveys. We counted all birds that we could see within 0.5 mile on either side of the boat. It is possible that we missed birds sitting on the water directly in front that were obstructed by the bow of the boat. If these birds flushed they would have been counted if they flew off to the right or the left and entered the field of view of the observers. The sampling distance was periodically checked with the range-finding function of the onboard radar in reference to visible objects such as buoys. Flight heights of the birds were estimated by referencing objects of known height such as the top of the wheelhouse, navigational buoys, and the Cape Wind test tower. Observers used binoculars as needed.

Boat surveys were conducted under weather conditions comparable to that of aerial surveys. Sampling under a variety of weather conditions, including inclement weather would have been desirable had time and resources permitted. Given the limitations on the latter, we chose to focus our surveys to maximize the detectability of birds in Nantucket Sound and Horseshoe Shoal. Most surveys were conducted between 9:00 a.m. and 12:00 p.m.

Individual birds of all species were identified with the aid of binoculars as needed. Numbers of Roseate and Common Tern sightings were recorded as described above in aerial surveys. Unless otherwise noted, any reference to ‘terns’ is to the combined total number of Roseate, Common, and undifferentiated Roseate/Common Terns.

RESULTS

Aerial Surveys

We completed ten aerial surveys; an additional survey on August 7 was not completed due to deteriorating weather conditions, but the data from this survey for the portion completed have been included in our analyses unless otherwise noted.

We observed 823 terns including 92 Common Terns, 14 Roseate Terns, and 717 Common/Roseate-type terns (Table 1) on all aerial surveys combined. The highest single-day count of 385 terns was recorded on August 17, and the second highest count of 183 terns was recorded on August 24 (Figure 3).

After excluding the one incomplete survey (to remove spatial biases), the majority of terns (71.2%, n = 558) were seen along transects 14-16 close to Monomoy NWR while 28.8% (n = 226) of all terns were counted within transects 1-13 (Figure 4). Twenty of 784 terns (or 2.5%) observed during all completed aerial surveys combined were counted over the Horseshoe Shoal project area, an area encompassing 12.2% of the total linear miles sampled in the study area. Proportional tern abundance in the two alternate study areas was also lower than expected if tern sightings had been evenly distributed across Nantucket Sound. However, if transects 14-16 are excluded from the analysis, 10.2% of terns were observed in the Monomoy-Handkerchief Shoal project area, 7.3% of the total miles surveyed (Table 3).

<u>Tern Behavior</u>

Among the 92 Common Terns counted in all aerial surveys, 11 (12.0%) were actively feeding, 80 (87.0%) were traveling, and one (1.1%) was resting on the water. Of the 14 Roseate Terns counted, one (7.1%) was actively feeding, 13 (92.9%) were traveling, and none were resting on the water. Of the 717 Common/Roseate type terns counted, 368 (51.3%) were actively feeding, 341 (47.3%) were traveling, and eight (1.0%) were resting on the water. Overall, 46.2% of terns were actively feeding, 52.7% were traveling, and 1.1% were resting on the water (Table 4).

We also analyzed behavior of terns recorded only on transects 1-13, excluding transects 14-16; the latter traversed shallow water close to Chatham's staging, feeding, and resting areas. These transects were excluded from this analysis because terns observed on these transects were more likely to have been feeding locally within the shallows off Monomoy NWR rather than traveling to Monomoy NWR from breeding sites or other areas. Of 32 Common Terns counted within transects 1-13, one (3.1%) was diving/feeding, 30 (93.8%) were traveling, and one (3.1%) was resting. Of seven Roseate Terns counted on these transects, all were traveling. Of 203 undifferentiated Common/Roseate type terns, 15 (7.4%) were diving/feeding, 183 (90.1%) were traveling, and five (2.5%) were resting. Overall, of all 242 terns observed on transects 1-13, 6.6% were actively feeding, 90.9% were traveling, and 2.5% were sitting on the water. Of the 35 terns observed over Horseshoe Shoals, 34 (97%) were observed traveling.

Most flying birds observed during aerial surveys appeared to be at or near the water surface, but because we lacked a useful frame of reference, accurate estimation of their flight heights was not possible. However, four terns observed on August 17 were observed traveling at heights estimated to be between 150 and 400 feet. Three of these high-flying terns were observed in the northeastern quadrant of the study area, while the fourth was observed roughly one-half mile to the north of the Horseshoe Shoal project area.

Non-tern Species

During the aerial surveys, we observed 21 other species of birds (see Table 5) and five non-avian species/groups – including 53 sea turtles (Table 6, Figure 5). The details of non-tern or non-avian species by survey date can be obtained by contacting the authors.

Boat Surveys

We completed six boat surveys within the survey period: August 11, August 19, August 30, and September 4, September 15, and September 23. A total of 36 terns were recorded on three of the six boat surveys: one tern on August 11, one tern on August 19, and 34 terns on September 4 (Table 2). Of 17 Common Terns, one (5.9%) was diving/feeding, 10 (58.8%) were flying, and six (35.3%) were resting. One Roseate Tern was observed traveling. Of 18 Common/Roseate type terns, all were traveling (Table 4). The altitude range of all but one of the traveling terns (n=29) was between 10 and 75 feet with an average height of 17 ft (SD=13). One Common/Roseate type tern was observed flying between 75 and 425 ft (Table 7), which is the height range of the rotor-swept zone for the proposed wind farm.

Seven other avian species and three avian groups were recorded during the six boat surveys including 18 scoters and 193 gulls (Table 8). Six individuals of these species/groups, all gulls, were observed flying within the rotor-swept zone. The relative distribution of flight heights for all birds observed during boat surveys is presented in Table 7.

DISCUSSION

We counted 92% fewer terns in the study area during 2004 than in 2003 and 86% fewer than in 2002 (Table 2, Figure 3). Our survey results from 2002 are not directly comparable to results from 2003 and 2004, because in 2002 we did not delineate a transect width (300 feet) for counting birds. Instead we counted all birds in view from the aircraft (Perkins et al. 2003). Though anecdotal, repeated surveys have indicated that detectability of terns rapidly diminishes beyond 300 feet. Therefore, though we believe that data are comparable between 2002 and other years, caution should be exercised when comparing tern abundances between years.

The average number of terns observed in Nantucket Sound per aerial survey in 2004 was less than 20% and 10% of the numbers observed in 2002 and 2003, respectively. These differences were significant ((Mann-Whitney U-test: 2004 vs 2002 – $z=2.91$, $P<0.01$; 2004 vs 2003 – $z=3.27$, $P<0.001$). For the purposes of these comparisons, data collected during incomplete surveys were omitted. This difference, however, was not consistent across the entire staging period. In both 2003 and 2004 the average number of terns observed per survey in the study area between August 7 and September 2 was nearly the same (mean=137.5 terns/survey in 2003 [n=6 surveys] versus mean=134.6 terns/survey in 2004 [n=5 surveys]).

In 2004, tern numbers in the survey area dropped rapidly during September 2004, in contrast to 2003. This pattern of decline during September was also observed in 2002, when tern numbers fell quickly in the second and third weeks of September. During September in both 2003 and 2004, single-day high counts of 8,000 common terns were observed from land-based observers in the area of Chatham/Monomoy NWR/South Beach (Bird Observer, 2004 and 2005).

Relatively few terns (Table 3) were observed during aerial surveys over the proposed Horseshoe Shoal project area during the pre-migratory staging period of 2004. All of the terns observed in the Horseshoe Shoal project area (n=21) were traveling. Additionally, all of these terns were observed either on August 17 (n=17) or on September 24, 2004 (n=4). The relative lack of tern sightings within the project area suggests that Horseshoe Shoal is not a primary feeding area for terns during the summer season or during the fall staging period (e.g., Perkins et al 2003).

Despite the reduced number of terns observed during the 2004 aerial surveys, the distribution pattern of terns across Nantucket Sound was generally consistent with patterns observed in 2002 and 2003. Abundance and distribution patterns in 2003 suggested that areas of tern concentration shifted during the second and third weeks of September from a more even distribution across Nantucket Sound in August to a more concentrated distribution in the shallow water section of the study area immediately west of Chatham and Monomoy NWR. In contrast, in 2004 terns were concentrated to the east of our survey grid in an area comprising South Monomoy Island, South Beach, and North Beach. We observed an average of 2,403 terns per survey (maximum=4,531) in the five extended surveys flown between September 7 and September 24 in that area (Figure 4).

Because of the limited area that we surveyed, our cumulative tern totals in 2002, 2003, and 2004 should not be used to draw broad conclusions about overall annual fluctuations in the size of the staging tern population in the region. Instead our data indicate the changes in local distribution of these birds from year to year, and they provide consistent information on within-season changes in tern distribution within the Sound.

In 2004, the overall lower number of terns in the latter half of the 2004 staging period (from September 4 to 24) was consistent throughout our survey area, not just in the transects closest to Monomoy NWR. We hypothesize that terns shifted their distribution in 2004 in response to a shift in location of primary prey such as sand lance (*Ammodytes* spp.). This shift resulted in lower concentrations of terns in the northeastern section of Nantucket Sound than previously observed in 2002 and 2003. The attraction to the Chatham-Monomoy NWR area is thought to be due, in part, to the presence of numerous sandbars and the favorable fishing conditions these bathymetric features produce. During the staging period, recent tern numbers derived from various land-based counts at South Beach in Chatham have numbered in the tens of thousands (e.g., Trull et al. 1999).

Feeding concentrations of seabirds are well known to shift with prey availability, which can vary at different spatial and temporal scales. Safina and Burger (1988) surmised that greater numbers of Common Terns off Long Island, New York tended to concentrate around fewer schools of prey fish in late July and August after stocks were reduced, possibly by seasonal influxes of predatory bluefish (*Pomatamus saltatrix*). These tern concentrations also tended to be in areas that had been ignored by terns earlier in the season (Safina and Burger 1988).

A more detailed understanding of factors affecting the distribution of *Ammodytes*, the terns' principle prey species, is important, especially if staging terns extend their primary foraging habitat range to areas farther offshore, such as Horseshoe Shoal and other shallow areas, where prey fish may congregate during times of low prey availability.

The original intention of these surveys was to provide information on tern distribution during the staging period as part of the avian risk assessment for the 130-turbine wind farm proposed for Horseshoe Shoal. One particular challenge is converting the results of our survey data into a measure of risk to terns if the wind farm on Horseshoe Shoal, the preferred location, is constructed. It is generally assumed that risk to birds is related to the amount time that birds spend in the vicinity of wind turbines, especially at rotor swept height. As a tern travels through the proposed project area it is at risk of colliding with the poles and rotors of the wind turbines. Our surveys provide information on the abundance and density of terns in Horseshoe Shoal. Future analyses should attempt to convert these parameters into the total number of terns traveling through the proposed project area.

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LITERATURE CITED

Bird Observer. 2003. Bird Observer of Eastern Massachusetts 31 (1): 35-53.

Bird Observer. 2004. Bird Observer of Eastern Massachusetts 32 (1): 49-66.

Bird Observer. 2005. Bird Observer of Eastern Massachusetts 33 (1): 53-69.

Gochfeld, M., J. Burger, and I. C. T. Nisbet. 1998. Roseate Tern (*Sterna dougallii*). *In* The Birds of North America, No. 370 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

Gove, G. W., R. H. Stymiest, and L. E. Taylor. 1984. Field Records September 1984. Bird Observer of Eastern Massachusetts 12 (6): 337-350.

Massachusetts Department of Fish and Game. 2004. Preliminary census numbers for shorebirds. MassWildlife News, October 26, 2004. http://www.mass.gov/dfwele/dfw/mwnews/dfw_mwnews_1004.htm

Perkins, S., A. Jones, and T. Allison. 2003. Survey of tern activity within Nantucket Sound, Massachusetts, during pre-migratory fall staging. Final report to the Massachusetts Technology Collaborative. Massachusetts Audubon Society, Lincoln, MA, 19 pages.

Perkins, S., T. Allison, A. Jones, and G. Sadoti. 2004a. A survey of tern activity within Nantucket Sound, Massachusetts, during the 2003 breeding season. Final report to the Massachusetts Technology Collaborative. 18 pp.

Perkins, S., T. Allison, A. Jones, and G. Sadoti. 2004b. A survey of tern activity within Nantucket Sound, Massachusetts, during the 2003 fall staging period. Final report to the Massachusetts Technology Collaborative. 24 pp.

Sadoti, G., T. Allison, S. Perkins, A. Jones. 2005. A survey of tern activity within Nantucket Sound, Massachusetts, during the 2004 breeding season. Final report to the Massachusetts Technology Collaborative. 22 pp.

Safina, C. and J. Burger. 1988. Ecological Dynamics Among Prey Fish, Bluefish and Foraging Common Terns in a Coastal Atlantic System. In*:* Burger, J., ed., Seabirds and Other Marine Vertebrates; Competition, Predation, and Other Interactions. Columbia University Press, New York, NY.

Trull P., S. Hecker, M.J. Watson & I.C.T. Nisbet. 1999. Staging of Roseate Terns *Sterna dougallii* in post-breeding period around Cape Cod, Massachusetts, USA. Atlantic Seabirds 1(4): 145-158.

U.S. Army Corps of Engineers. 2004. Draft Environmental Impact Statement for the Cape Wind Energy Project, Nantucket Sound, Massachusetts. U.S. Army Corps of Engineers, Concord, MA.

U.S. Fish and Wildlife Service. 1986. Species profiles: life histories and environmental requirement of coastal fishes and invertebrates (North Atlantic): sand lance. Biological report 82 (11.66).

U.S. Fish and Wildlife Service. 1998. Roseate Tern Recovery Plan: Northeastern population, First Update. USFWS, Hadley, MA.

Veit, R. R., and W. R. Petersen. 1993. Birds of Massachusetts. Massachusetts Audubon Society, Lincoln, MA.

Table 1. Number of terns seen by species and date of survey during aerial surveys in 2004 premigratory staging season. Survey duration is reported in total hours and minutes. August 7 did not include transects 1 through 3 due to deteriorating weather conditions. Birds in the Common/Roseate Tern spp. column are undifferentiated.

Date	**Survey Duration**	**Common Tern**	**Roseate Tern**	**Common/ Roseate Tern spp.**	**Total**
7-Aug-04	1:58	15	3	14	**32**
13-Aug-04	2:24	3	3	46	**52**
17-Aug-04	2:10	49	3	333	**385**
24-Aug-04	2:13	10	0	173	**183**
2-Sep-04	2:17	7	2	19	**28**
4-Sep-04	2:41	4	2	8	**14**
7-Sep-04	2:21	0	1	27	**28**
11-Sep-04	2:28	4	0	7	**11**
14-Sep-04	2:42	0	0	12	**12**
21-Sep-04	2:14	0	0	47	**47**
24-Sep-04	2:32	0	0	31	**31**
Total	**26:00**	**82**	**14**	**717**	**823**

Table 2. Total number of terns counted in 2002–2004 on pre-migratory staging period 1) boat surveys of Horseshoe Shoal, Nantucket Sound, Massachusetts and 2) during aerial surveys of a broader area. Due to removal of birds observed outside of study area boundaries or resting on beaches/shallows from 2002 and 2003 data, these numbers may not be the same as presented in Perkins, et al. (2003 and 2004b). The Common/Roseate Tern column includes both Roseate and Common Terns that could not be reliably distinguished.

1. Boat Surveys

Year	**Surveys**	**Common Terns**	**Roseate Tern**	**Common/ Roseate Tern spp.**	**Total**
2002	4	31	1	11	**43**
2003	4	24	0	0	**24**
2004	6	17	1	18	**36**
Total	**14**	**72**	**2**	**29**	**103**

2. Aerial Surveys

Year	**Surveys**	**Common Terns**	**Roseate Tern**	**Common/ Roseate Tern spp.**	**Total**
2002	11	1,975	419	3,153	**5,547**
2003	13	1,812	376	7,889	**10,077**
2004	11	92	14	717	**823**
Total	**35**	**3,879**	**809**	**11,759**	**16,447**

Table 3. Proportional abundance of terns observed on aerial surveys during the pre-migratory staging period (August - September) of Nantucket Sound, Massachusetts, 2002-2004. Survey length (in miles) contained within each alternative project area and non-shoal area is indicated under each project area name. Results are presented for two survey area extents; 1) one in which we controlled for bias resulting from the close proximity of several survey transects to the Monomoy NWR tern breeding colony, and 2) one for which this bias was not controlled. Alternative project areas with proportional tern abundance greater than the proportional area are shown in bold. Total numbers of birds observed in each survey area and in each year are noted below each proportion value. Incomplete surveys were excluded from analysis.

A. Transects 14-16 excluded:

	Alternative project areas			
	Horseshoe Shoal (28.7 mi)	**Monomoy-Handkerchief Shoal (15.7 mi)**	**Tuckernuck Shoal (23.5 mi)**	**Non-project areas (153.2 mi)**
	Proportion of survey miles in study area			
	12.2%	7.3%	11.3%	68.7%
Year (# of surveys)	**Proportion of terns observed (# of terns)**			
2002 (n = 11)	1.5% (n = 35)	**10.6%** (n = 247)	0.8% (n = 18)	87.1% (n = 2,033)
2003 (n = 11)	2.2% (n = 82)	**18.4%** (n = 697)	0.3% (n = 13)	79.1% (n = 3,004)
2004 (n = 10)	8.8% (n = 20)	**10.2%** (n = 23)	6.6% (n = 15)	74.3% (n = 168)

B. Transects 14-16 included:

	Alternative project areas			
	Horseshoe Shoal (28.7 mi)	**Monomoy-Handkerchief Shoal (15.7 mi)**	**Tuckernuck Shoal (23.5 mi)**	**Non-project areas (153.2 mi)**
	Proportion of survey miles in study area			
	10.9%	6.9%	10.9%	72.1%
Year (# of surveys)	**Proportion of terns observed (# of terns)**			
2002 (n = 11)	0.8% (n = 35)	5.3% (n = 247)	0.4% (n = 18)	93.6% (n = 4,359)
2003 (n = 11)	0.8% (n = 82)	**7.0%** (n = 697)	0.1% (n =13)	92.1% (n = 9,217)
2004 (n = 10)	2.6% (n = 20)	2.9% (n = 23)	1.9% (n = 15)	92.6% (n = 726)

Table 4. Percent of total terns observed exhibiting one of three behaviors during 2002 – 2004 pre-migratory staging period boat surveys on Horseshoe Shoal, Nantucket Sound, Massachusetts (1) and during aerial surveys of a broader area on transects 1-13 (14 – 16 excluded) (2). Traveling birds were observed flying at a generally constant speed and height, and in one clear direction. Actively feeding birds were observed flying more erratically than traveling birds, either circling, swooping, or diving. Resting birds were observed sitting on the water's surface. Due to removal of birds observed outside of study area boundaries or resting on beaches/shallows from 2002 and 2003 data, these numbers may not be the same as presented in Perkins, et al. (2003 and 2004b).

1. Boat surveys

Year	**Surveys**	**Terns**	**Feeding**	**Traveling**	**Resting**
2002	4	43	46.5%	53.5%	0.0%
2003	4	24	62.5%	33.3%	4.2%
2004	6	36	2.8%	80.6%	16.7%

2. Aerial surveys

Year	**Surveys**	**Terns**	**Feeding**	**Traveling**	**Resting**
2002	11	5,547	52.9%	39.3%	0.2%
2003	13	10,077	66.8%	31.5%	1.7%
2004	11	823	46.2%	52.7%	1.1%

Table 5. Total number of all birds observed on pre-migratory season aerial surveys in 2002, 2003, and 2004. Due to removal of birds observed outside of study area boundaries or resting on beaches/shallows from 2002 and 2003 data, these numbers may not be the same as presented in Perkins, et al. (2003 and 2004b).

Species	2002	2003	2004	Total
Common Eider	8	1	23	**32**
Surf Scoter	0	4	131	**135**
White-winged Scoter	14	41	212	**267**
Scoter species	0	0	743	**743**
Red-breasted Merganser	0	1	0	**1**
Duck species	0	0	1	**1**
Red-throated Loon	0	0	3	**3**
Common Loon	0	3	75	**78**
Loon species	1	0	47	**48**
Wilson's Storm-Petrel	7	2	53	**62**
Northern Gannet	13	0	0	**13**
Double-crested Cormorant	612	45	680	**1,337**
Egret species	0	0	1	**1**
Osprey	0	1	0	**1**
American Oystercatcher	4	24	1	**29**
Shorebird species	154	18	11	**183**
Jaeger species	2	0	3	**5**
Laughing Gull	23	6	14	**43**
Bonaparte's Gull	5	2	6	**13**
Herring Gull	198	243	400	**841**
Greater Black-backed Gull	288	442	421	**1,151**
Black-legged Kittiwake	0	0	1	**1**
Gull species	649	69	640	**1,358**
Common/Roseate Tern	5,547	10,077	823	**16,447**
Black Tern	1	0	0	**1**
Least Tern	9	63	15	**87**
Undifferentiated passerines	0	1	1	**2**
Total	**7,535**	**11,043**	**4,305**	**22,883**

Table 6. Incidental observations of non-avian species made during 2002 - 2004 pre-migratory staging season aerial surveys of Nantucket Sound, Massachusetts.

Species/Taxa	2002	2003	2004	Total
Ocean Sunfish	4	8	5	17
Sharks	0	2	1	3
Turtles (all)	34	28	53	115
Leatherback Turtles	(6)	(8)	(41)	(54)
Turtles (non-Leatherback)	(6)	(4)	(12)	(22)
Turtles (unidentified)	(22)	(16)	(0)	(38)
Seals	5	4	4	13
Rizzo's Dolphin (dead)	0	0	1	1
Total	**43**	**42**	**64**	**149**

Table 7. Flight heights of all avian species observed traveling during 2002 - 2004 pre-migratory staging period boat surveys of Horseshoe Shoal, Nantucket Sound, Massachusetts. Rotor-swept zone is defined as an altitude range of 75 to 425 ft above mean sea level. Percentage of birds in the rotor-swept zone is calculated from all birds observed of a given species in a given year. Flight heights are not included for birds observed actively feeding. Species with no observations of flying individuals are not listed.

	2002 (n = 4 surveys)								2003 (n = 4 surveys)								2004 (n = 6 surveys)							
			Flying altitude								Flying altitude								Flying altitude					
Species	**n (all)**	**n (flying)**	**Mean**	**SD**	**Min**	**Max**	**# in rotor zone**	**% in rotor zone***	**n (all)**	**n (flying)**	**Mean**	**SD**	**Min**	**Max**	**# in rotor zone**	**% in rotor zone***	**n (all)**	**n (flying)**	**Mean**	**SD**	**Min**	**Max**	**# in rotor zone**	**% in rotor zone***
White-winged Scoter	16	16	20	0	20	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Black Scoter	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	9	4	0	4	4	-	-
Loon species	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	4	-	4	4	-	-
Wilson's Storm-Petrel	1	1	2	-	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Double-crested Cormorant	11	4	30	0	30	30	-	-	1	1	10	-	10	10	-	-	4	4	22.5	20.2	5	40	-	-
Laughing Gull	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	2	50	0	50	50	-	-
Herring Gull	4	2	27.5	3.5	25	30	-	-	1	1	20	-	20	20	-	-	85	63	24.8	61	3	300	3	3.5
Greater Black-backed Gull	-	-	-	-	-	-	-	-	5	3	20	0	20	20	-	-	65	35	20.6	29.6	3	80	2	3.8
Gull species	-	-	-	-	-	-	-	-	2	1	20	0	20	20	-	-	38	27	14.1	24.7	4	100	1	2.6
Common/Roseate Tern	43	23	22	9	1	30	-	-	24	8	30	0	30	30	-	-	36	29	16.6	12.9	10	75	1	2.8
Tree Swallow	-	-	-	-	-	-	-	-	1	1	30	-	30	30	-	-	-	-	-	-	-	-	-	-
Undifferentiated passerines	-	-	-	-	-	-	-	-	1	1	50	-	50	50	-	-	6	6	10	0	10	10	-	-
Total (all species)	**75**	**66**	**21.9**	**8**	**1**	**30**	**-**	**-**	**53**	**16**	**26.9**	**8.7**	**10**	**50**	**-**	**-**	**248**	**178**	**18.2**	**37.3**	**3**	**300**	**7**	**2.8**

*calculated as a percentage of all birds observed of a given species

Table 8. Total number of all birds observed on premigratory season boat surveys of Horseshoe Shoal, Nantucket Sound, Massachusetts during 2002–2004. Due to removal of birds observed outside of study area boundaries or resting on beaches/shallows from 2002 and 2003 data, these numbers may not be the same as presented in Perkins, et al. (2003 and 2004b).

Species	**2002**	**2003**	**2004**	**Total**
White-winged Scoter	15	6	0	**21**
Black Scoter	0	0	9	**9**
Scoter species	0	12	0	**12**
Common Loon	0	0	1	**1**
Loon species	0	0	1	**1**
Wilson's Storm-Petrel	1	0	0	**1**
Double-crested Cormorant	11	1	4	**16**
Laughing Gull	0	0	4	**4**
Bonaparte's Gull	0	0	1	**1**
Herring Gull	4	1	85	**90**
Greater Black-backed Gull	0	5	65	**70**
Gull species	0	2	38	**40**
Common/Roseate Tern	43	24	36	**103**
Passerines	0	2	6	**8**
Total	**74**	**53**	**250**	**377**

Figure 1. Nantucket Sound study area and associated features, including aerial and boat transect routes, major tern colonies, natural features, and polygons used for analysis of tern abundance on Horseshoe Shoal and alternative shoal areas.

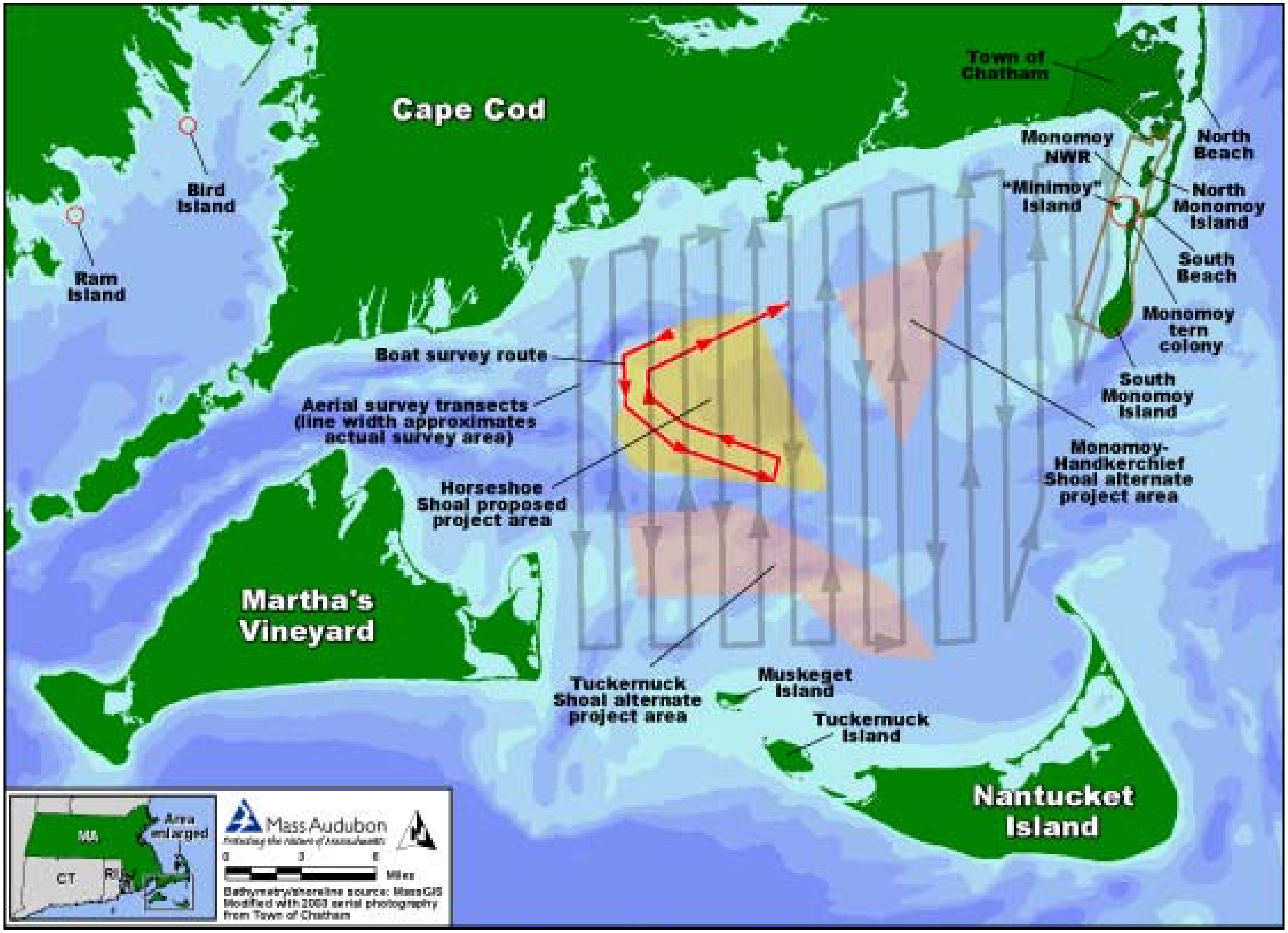

Figure 2. Viewing angles and distances used in aerial surveys (derived from figure drawn by Doug Forsell, U. S. Fish and Wildlife Service)

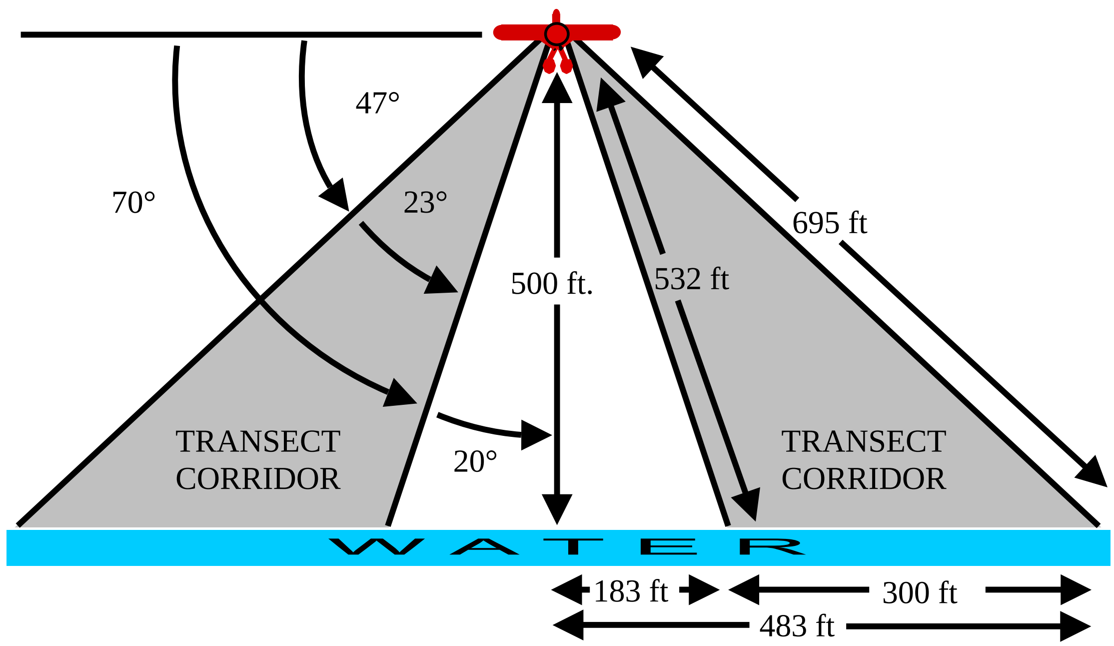

Figure 3. Total numbers of tern species recorded during pre-migratory staging period aerial on surveys of Nantucket Sound, Massachusetts, 2002–2004. Survey duration is indicated in parentheses. Surveys on August 7 and 27, 2003 and August 7, 2004 were not completed due to deteriorating weather conditions. Horizontal axes (date) are the same on all charts. Tern spp. refers to undifferentiated Common/Roseate Terns.

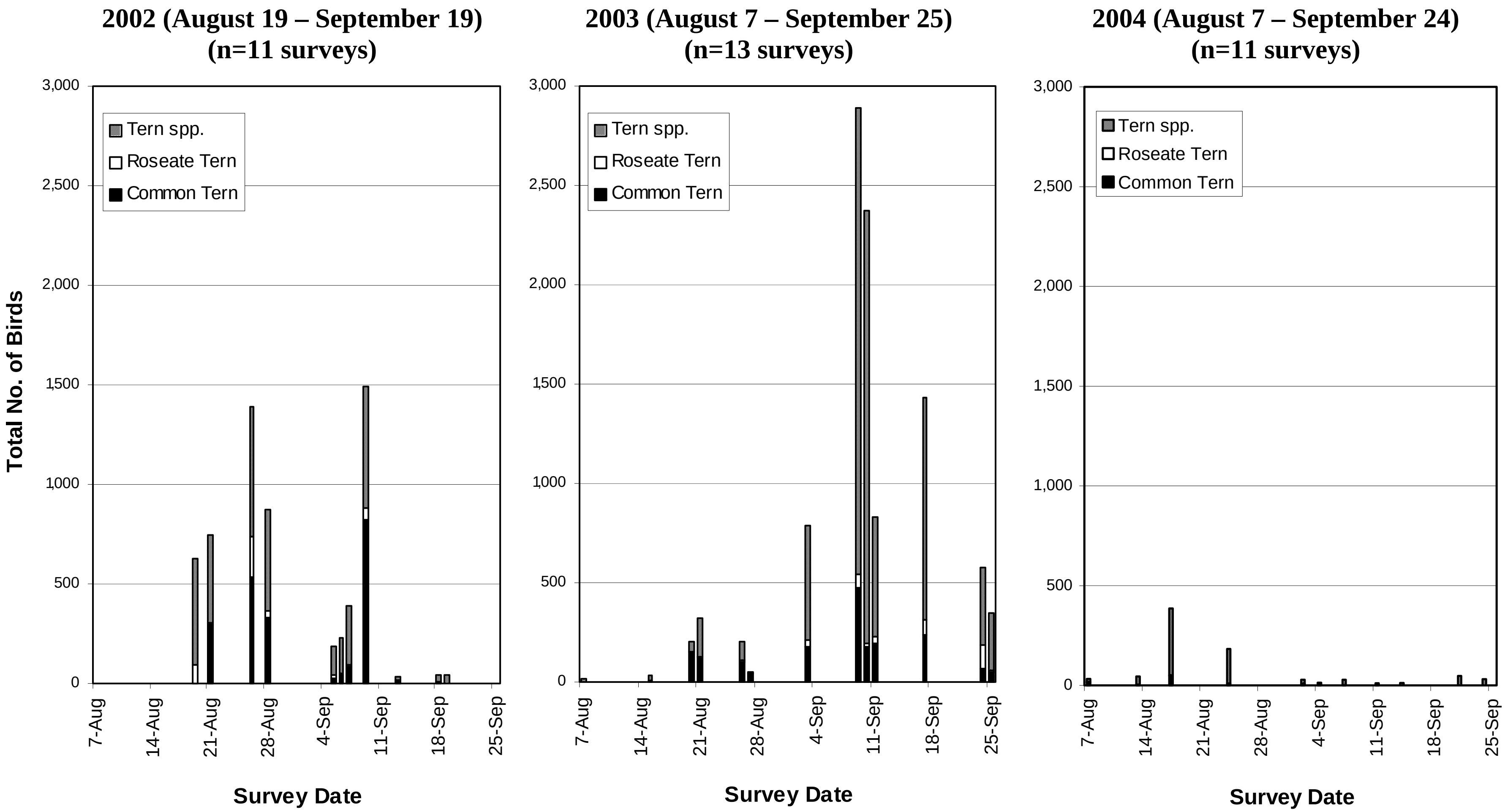

Figure 4. Locations and numbers of Roseate Terns, Common Terns, and undifferentiated Roseate/Common Tern species observed on aerial surveys during the pre-migratory staging period, 2004. Eleven surveys were made between August 7 and September 24, 2004. Observations outside study area boundary are from five surveys conducted September 7 – 24, 2004.

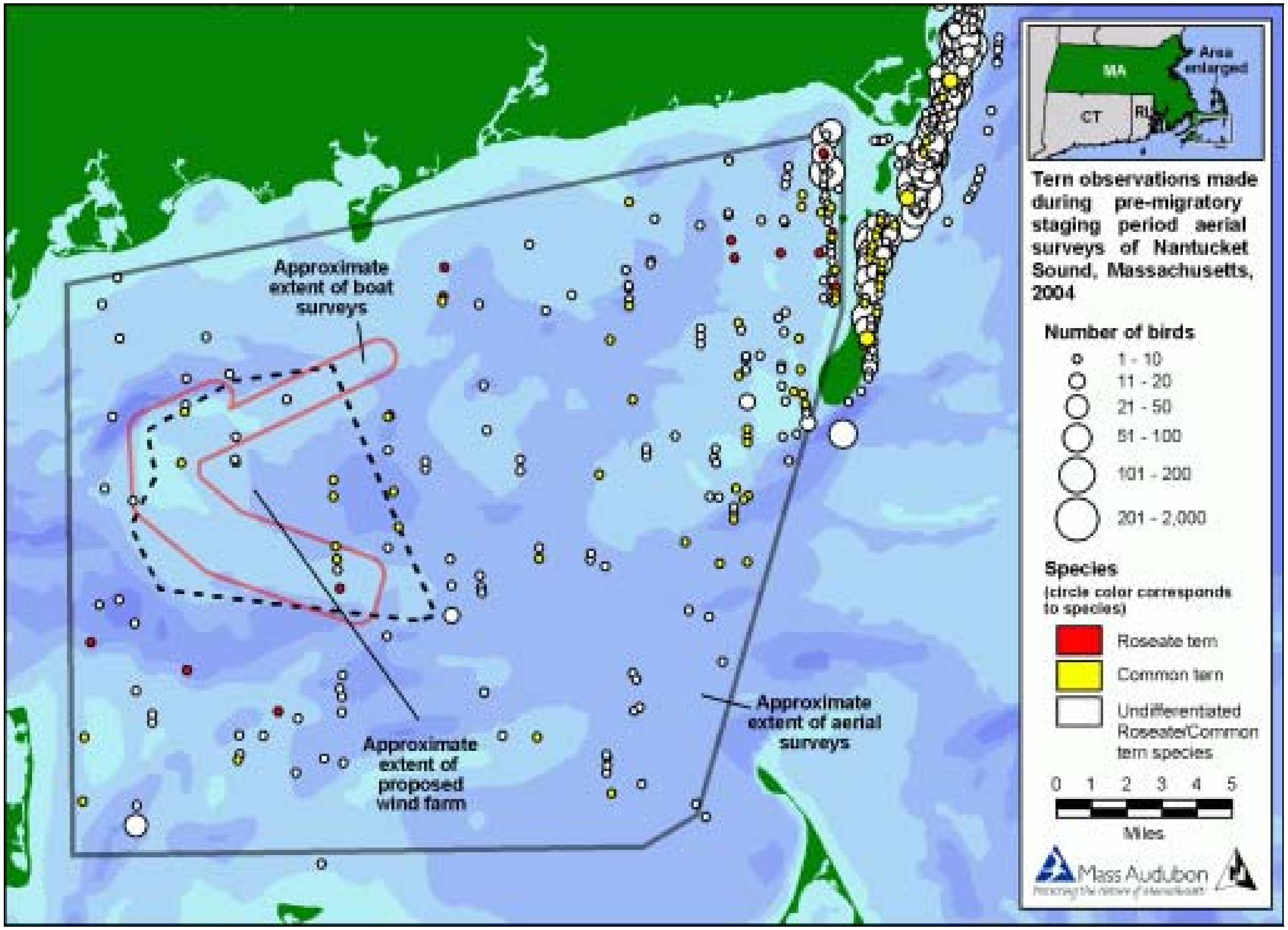

Figure 5. Incidental observations of 115 sea turtles made during 35 pre-migratory staging period aerial surveys of Nantucket Sound, Massachusetts, 2002-2004. All observations are of single individuals. Observation locations were shifted slightly to improve readability of the map.